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# Thyroid Cancer in Children and Adolescents

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Additional information is available at the end of the chapter

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## Abstract

Thyroid cancer is the most common endocrine malignancy in children and adolescents. Although the basis of the thyroid cancer management in children is the same as those of the adults, thyroid cancer may behave different in pediatric population than adults. Unlike adults, children usually present with more advanced disease and the risk of recurrence and metastases are higher. However, the prognosis and survival of pediatric thyroid cancer is better than those of adults. This chapter will review the frequency, epidemiology, and clinical behavior of pediatric thyroid cancer with emphasis on the appropriate management in nuclear medicine.

**Keywords:** thyroid cancer, iodine scan, thyroid, thyroglobulin, ultrasound, children, adolescents

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## 1. Introduction

Thyroid cancer is the most common endocrine malignancy; in 2014, it affected >60,000 people in North America [1]. Only approximately 2% of thyroid cancer has been reported to occur in children and adolescents [2]. The most frequent type of thyroid cancer is the differentiated type, mainly papillary (90–95%) and to a lesser extent follicular (~5%) [3–5]. Conventionally, thyroid cancers in both adult and pediatric patients are managed by total or near-total thyroidectomy, with resection of the affected regional lymph nodes, followed by ablation of the thyroid remnant and associated metastases using  $^{131}\text{I}$ . The patients then receive subsequent treatment involving thyroid-stimulating hormone (TSH) suppression with levothyroxine [6, 7]. Accurate staging (to avoid overtreatment) and the choice of surveillance methods are important in children. On one hand, the risk of recurrence and regional lymph node involvement are higher in children. On the other hand, because of the long lifespan of these patients and their susceptibility to

treatment side effects, the risk of long-term complications associated with therapy (e.g., high doses of radioiodine) is higher than those of adults [8, 9]. In this chapter, the management of thyroid cancer in children is discussed, with the focus on nuclear medicine therapies.

## 2. Epidemiology

In general, the risk of thyroid cancers has increased globally over the last decades [3, 10]. Unlike many other cancers, thyroid cancer is rare in early childhood; the incidence increases during adolescence and early adult life and will reach a plateau at age approximately 40 years with little subsequent changes at older ages [11]. Thyroid cancer is the eighth most common cancer diagnosed in patients aged 15–19 years, and is the second most common cancer among adolescent girls [12, 13]. Many other cancers are rare in early childhood and are common in older people; some (usually those with immature tumor cells such as retinoblastoma or neuroblastoma) are more common in early childhood and are rare in adults [11]. Thyroid nodules are more common in teenagers than in younger children [14]; however, the risk of malignancy is greater when a nodule is diagnosed in children aged <10 years [15].

## 3. Risk factors

Age, sex, family history of thyroid disease, and radiation exposure are among the risk factors affecting the frequency of thyroid cancers in children. Generally, differentiated thyroid cancer (DTC) is more common in adolescent girls [2]. The sex distribution of thyroid carcinoma differs between adults and children. In adults, thyroid cancer is four times more common in women than in men. In the pediatric population, the incidence of thyroid cancer is only slightly higher in younger girls before puberty as compared with boys (female-to-male ratio, 1.5:1). The risk of thyroid cancer then increases rapidly and reaches a peak during puberty in teenage girls (female-to-male ratio, 3:1 to 14:1) [16–18]. Although it has not yet been confirmed, sex hormones may play a major role in the rapid increase in the incidence of thyroid cancer in female individuals during puberty [19].

The higher frequency of thyroid cancers after radiotherapy involving the neck has been confirmed in patients who were treated with external radiation for conditions such as tinea capitis, chronic tonsillitis, acne, and thymus hyperplasia [20, 21], and in children years after the Chernobyl incident [22, 23]. Analysis of the age of individuals at the time of radiation exposure showed that younger children had the highest risk of thyroid carcinoma after the Chernobyl incident [24].

## 4. Presentation

An asymptomatic neck mass (located in either the thyroid bed or elsewhere in the neck as an enlarged lymph node) is usually the first clinical presentation of thyroid cancer in children [25].

The possibility of malignancy increases if the mass is firm, nonmobile with associated lymphadenopathy, and/or there is vocal cord paralysis [25]. At presentation, the tumor size is often greater in children than in adults [26, 27]. The frequency of regional lymph node involvement is also higher in children relative to adults. More than half of the patients (60–90%) will have regional lymph node involvement either at diagnosis or on follow-up [8, 25, 27].

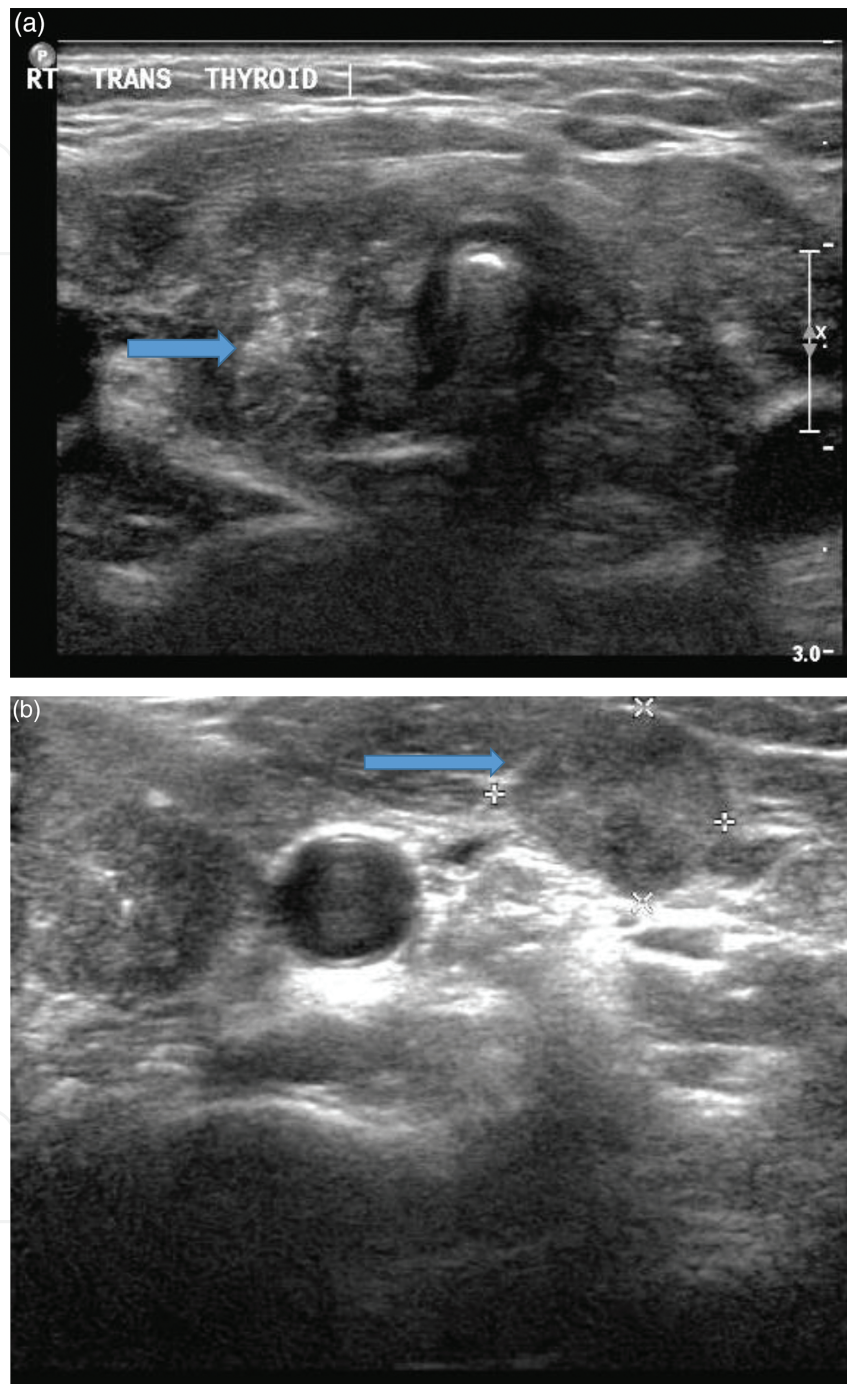
Lung metastasis is the most common site of distant metastases [28, 29]. Presentation with lung symptoms is very rare. Lung metastasis is more commonly seen in patients with extracapsular invasion, bilateral tumors, and in patients aged <7 years at diagnosis [30, 31]. In our experience, we found  $\leq 20\%$  of pulmonary metastases either at presentation or in follow-up studies [32]; all of them had a thyroglobulin (Tg) level of >10 ng/mL. In contrast to adults, pulmonary metastases in children are usually miliary and rarely nodular [30, 31]. Metastases to the lungs are functional in 95% of the cases. Metastases to the bone or central nervous system are very rare [28, 29, 33]. Thyroid function tests are usually normal in pediatric patients with DTC at presentation [25].

## 5. Management

The management of children with DTC should be undertaken by a medical team with appropriate experience and skills. The treatment of thyroid cancer in adult patients has been studied in detail by several investigators, and general guidelines exist. Pediatric oncologists have attempted to extrapolate from these guidelines, but there are insufficient data to answer many questions regarding children. Patients with thyroid cancer require the assistance of a diversified group of healthcare providers during literally every step of their care, from the time of diagnosis to the extended period of follow-up. The American Thyroid association (ATA) 2015 guidelines endeavor to summarize, in a practical way, the optimal management of patients with thyroid cancer; they detail how the fabric of their care is carefully woven by a group of providers with specialized skills, each of whom adds a unique component regarding the patient's overall care [34]. Without this broad multidisciplinary approach, gaps may occur at every turn in management, which may pose serious obstacles in achieving the best long-term results for the patients.

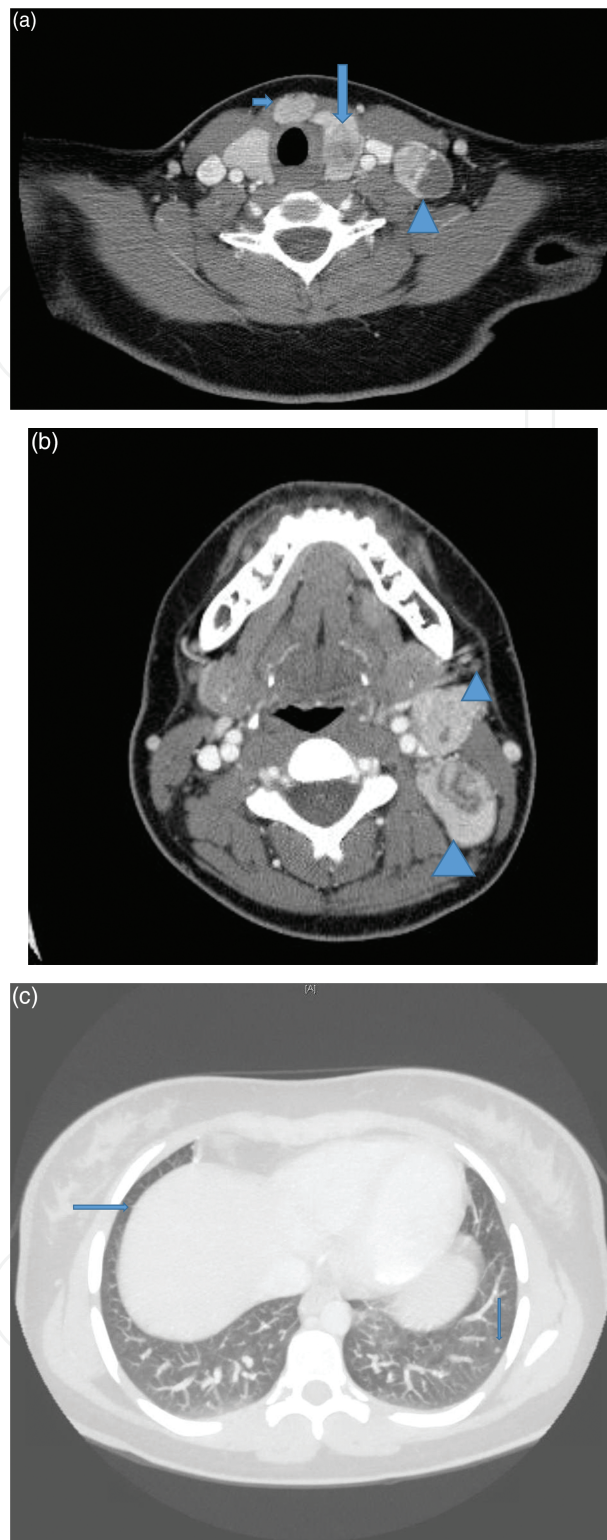
Generally, after a comprehensive analysis of patient history and physical examination, further investigation using high-resolution ultrasound (US) is recommended for the diagnosis of solid thyroid nodules, and to check for extrathyroid extension of the disease and regional neck lymph node involvement (**Figure 1**). This is frequently followed by fine needle aspiration (FNA) of the nodule, usually under the guidance of US [35, 36]. According to the pediatric-specific ATA guidelines recommendations, the US characteristics and clinical context, rather than size alone, should be used to determine if nodules warrant FNA [34]. Moreover, in children it is recommended that all FNAs are performed under US guidance [34]. Evaluation of regional lymph node involvement is important because children with evidence of palpable cervical lymph node disease at diagnosis are more likely to have multifocal disease (89 vs. 16%), an increased risk of pulmonary metastasis (20 vs. 0%), and an increased risk of persistent

(30 vs. 0%) and/or recurrent (53 vs. 0%) disease (**Figures 2 and 3**), as compared with children without gross nodal disease [37, 38].

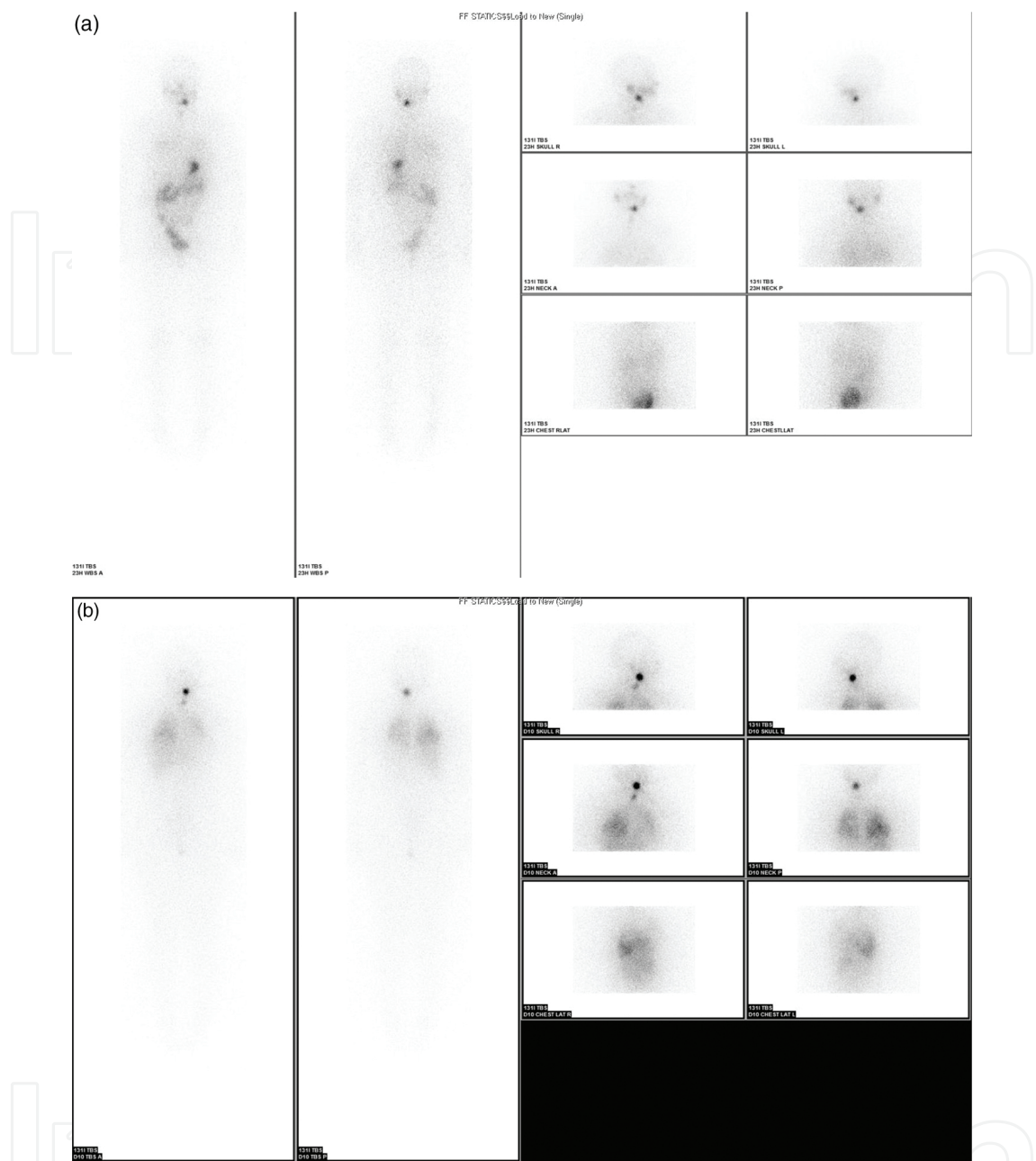


**Figure 1.** Ultrasound in a 10-year old boy with history of large posterior fossa brain tumour and panhypopituitarism, on thyroid replacement treatment: the patient presented with bilateral vocal cord weakness and stridor. Thyroid gland was enlarged with heterogeneous parenchyma and small foci of calcification (arrow in a). There were enlarged cervical lymph nodes with lost central echogenic hilum and increased short-to-long axis ratio (S/L)  $>0.5$  (b) which is suggestive of malignant infiltration, one of them showed in (b) (arrow). Papillary thyroid cancer was proved on histopathology with neck lymph nodes involvement.





**Figure 2.** Fifteen-year old girl referred to the clinic for a neck mass. Axial enhanced CT image (a and b) shows a heterogeneous nodule in the left thyroid lobe (big arrow) with enhancing large cystic nodal lymph nodes (arrowheads) in the left levels IIa, IIb, and IV in addition to level VI or Delphian nodes (small arrow). Papillary thyroid carcinoma with lymph nodes involvement was proven on histopathology. CT scan was suggestive for lung metastases (c) with small nodules in both lungs (arrows).



**Figure 3.** Status postoperative (total thyroidectomy) in the same patient presented in **Figure 2**. Diagnostic whole-body iodine scan after 2 mCi I-123 (a) demonstrated mild residual thyroid activity with a focus in the left submandibular region that might represent lymph node metastatic lesion. There was suspicion of lung metastases on chest CT scan (please see **Figure 2c**). The patient was treated with 145 mCi. On posttherapy scan (b) 7 and 10 days after a therapeutic dose of radioiodine, bilateral chest activity with no definite focus was noted due to pulmonary metastatic.

According to the ATA guidelines for pediatrics, children with papillary thyroid cancer can be divided into low, intermediate, or high risk, based on the clinical presentation, tumor size, and evidence of regional invasion and metastasis [34]. Low-risk patients are those with a cancer confined to the thyroid with no regional lymph nodes involvement or with incidental micro-metastasis to a small number of central neck lymph nodes. If the patient has extensive central lymph nodes involvement (level VI; pretracheal, paratracheal, prelaryngeal/Delphian lymph

nodes), or minimal lymph nodes involvement in the rest of the neck, the patient is categorized as intermediate risk. Locally invasive disease (in the thyroid) or extensive neck lymph nodes involvement (other than region VI), or distant metastases will put the patient into the high-risk group [34]. Similar to adults, the cornerstone of the therapy is based on surgery, radioiodine ablation/therapy, and thyroid hormone replacement/suppression therapy.

## 6. Surgery

Except under special conditions, it is recommended that more comprehensive thyroid surgery is performed in pediatric patients; this is because of the higher incidence of bilateral and multifocal disease (30 and 65%, respectively) [39–41]. Thyroid lobectomy alone may be sufficient for small unifocal cancers (<1 cm), with no capsular invasion or lymph node involvement, without a prior history of radiotherapy or a family history of thyroid cancer [34]. In comparison with lobectomy, total thyroidectomy has a lower risk of recurrent/persistent disease and subsequent second surgical procedures [34, 40, 42, 43]. Central neck dissection is recommended for patients with evidence of gross extrathyroidal invasion and/or locoregional metastasis on preoperative staging or during surgery [34]. If there is no evidence of gross extrathyroidal invasion and/or locoregional metastasis, prophylactic central neck dissection may be routinely performed [34]. The decision is made based on tumor focality and size, and the experience of the surgeon [34]. Prophylactic lateral neck dissection (levels III, IV, anterior V, and II) is not recommended routinely, unless there is histopathological proof of lateral neck lymph node involvement [34].

## 7. Radioactive iodine ( $^{131}\text{I}$ ) ablation and therapy

Typically, there is remnant thyroid tissue after a total or near-total thyroidectomy, mainly because of the presence of normal thyroid tissue around the nerves or Berry's ligament. Because multifocal papillary cancer is relatively common in children, most authors recommend radioiodine ablation therapy in younger patients [25, 44]. Ablation therapy presumably not only destroys normal residual thyroid tissue but also possible micrometastases [45]. Moreover, follow-up Tg measurement is easier after radioiodine ablation therapy [46, 47]. In other words, if a patient receives radioiodine ablation therapy and the Tg level reaches an undetectable level, a subsequent rise in Tg level is highly suspicious of recurrence. In contrast, a rise in Tg level in a patient who did not receive ablation therapy may be the result of tumor recurrence or the regrowth of normal thyroid tissue [48, 49]. In the majority of cases, a single radioiodine treatment is sufficient for ablation. However, in some cases more than one treatment is required for complete ablation. It has not been proven in the pediatric population if the response to the first ablation therapy has any prognostic value.

Radioiodine can be provided in liquid and capsule forms. Although selection of the type of administration depends on patient preference, the capsule form is usually preferred to ensure



that the activity is fully delivered to the stomach. In some cases, an antiemetic medication is also required before administration of the radioiodine. If it is not clear that the patient can tolerate the capsule form, an empty gelatin capsule can be tried before the actual radioiodine capsule.  $^{131}\text{I}$  is also used for the treatment of known or suspected viable malignant disease in patients with DTC to destroy or control the disease. The dose of radioiodine for therapy mainly depends on the presence or absence of metastases, and the organs involved. The diagnostic and therapeutic role of radioiodine must be individualized to each patient through collaboration between the patient's endocrinologist/referring physician and the nuclear medicine physician [50]. Tumor radioiodine avidity and sensitivity to radioiodine can vary significantly between children with DTC, and even in the same patient over time [50, 51]. The selected dose of radioiodine for therapy depends on many factors including the presence or absence of metastases, and intermediate-/high-risk or low-risk patients. There are formulas for the estimation of relative pediatric doses [51]. In general, it is suggested that the  $^{131}\text{I}$  doses should not exceed 200 mCi (7400 MBq) for each patient with a total cumulative dose limited to 1000 mCi (37,000 MBq). The absorbed dose to the red marrow should not exceed 200 cGy, and 48-hour whole-body retention should not reach 120 mCi (4440 MBq) to minimize the risk of secondary acute myelogenous leukemia (AML). The 48-hour whole-body retention of activity should be limited to 80 mCi (2960 MBq) in the setting of pulmonary metastases, to minimize the risk of pulmonary fibrosis [50, 51]. In certain cases, especially with pulmonary metastases, formal dosimetry should be performed in children with avid pulmonary metastases [50, 51]. Dosimetry before  $^{131}\text{I}$  therapy can also be considered in small children and in patients with a limited bone marrow reserve [34]. If there is a need to repeat the  $^{131}\text{I}$  therapy, an interval of  $\geq 12$  months is suggested to minimize the risk of secondary AML [50].

In many European and Asian countries, the patient is admitted 2 or 3 days after radioiodine ablation/therapy to minimize radiation exposure to the public. In North America, however, many centers allow the patients to go home after a therapeutic dose of radioiodine [52]. In our center, patients receiving therapeutic radioiodine doses of  $>30$  mCi (1.1 GBq) up to and including 200 mCi (7.4 GBq) can be managed on an outpatient basis, provided that the estimate of radiation exposure to the general public falls within regulatory limits. According to our institutional protocol, an adult family member who is considered to be the primary caregiver is exempt from the 1 mSv public dose limit; however, dose exposure should not exceed 5 mSv for the course of the treatment [53]. Our pediatric patients would prefer to be isolated in their homes rather than be confined in the hospital when medical care is not required. To achieve this, the patient and family must be willing to temporarily modify their lifestyles and comply with the instructions provided (**Table 1**). **Table 2** is an example of a questionnaire for an outpatient therapy with  $^{131}\text{I}$  in our institution. Exclusion criteria include patients requiring medical care during the course of the constrained period, any socio-economical factor that would inhibit compliance, and the inability of the primary caregiver or the patient to follow the radiation safety instructions. In a recent study, despite poor compliance with the radiation safety recommendations for patients treated with 100 mCi (3.7 GBq), caregivers received a low measured radiation exposure [54]. In this study, excessive radiation exposure was only seen when the caregivers stayed close to the patient for more than 5.8 hours during the first 3 days after radioiodine treatment [54].

Patients receiving therapeutic radioiodine doses of greater than 30 mCi (1.1 GBq) up to and including 200 mCi (7.4 GBq) can be managed on an outpatient basis provided that the estimate of radiation exposure to the general public fall within regulatory limits.

#### Procedure

1. The treating physician will conduct an assessment to determine suitability for outpatient treatment. The decision will be based on the patient's or family's response to a questionnaire regarding family members, circumstances and the assurance of compliance with the radiation safety instructions. See **Table 2**.
2. The treating physician will discuss the patient's suitability for this protocol with the radiation safety officer (RSO) or trained designate. In the case of noncompliance with the restrictions given, an estimate of the maximal dose to an individual in the patient's environment should be estimated and taken into account in the decision process.
3. The patient and family will be provided with appropriate written and oral information and instruction about the requirements for treatment. The RSO will verify that the patient and family understand what is required of them and that they are willing to comply with the requirements.
4. Approval for outpatient management of radioiodine therapy must be obtained from the RSO prior to scheduling the therapy.
5. An effort should be made to reduce doses to family members to levels that are as low as reasonably achievable (ALARA) with economic and social factors being taken into account. Dose reductions may require a detailed assessment of family activities to determine where modification in lifestyle can best be made to reduce doses without unnecessary restrictions. One example of a modification would be to have the patient spend the "isolation" period with a compliant grandparent, away from other siblings or a pregnant parent.
6. A primary caregiver will be identified. Since this person will likely receive a higher radiation dose during the course of the patient's treatment, a dose calculation for this person will be made based on activity and occupancy factors during constrained activity for 3 days.
7. On the day of treatment, the RSO (or trained designate) and treating physician will reassess the patient's compliance and give the written and oral precautions for radiation safety. The patient and/or parent will sign two copies of the instructions. One copy will be given to the patient and the other will be retained for the departmental patient record.
8. The therapy dose will be administered and the patient will be discharged.

**Table 1.** The instructions to assess the patient for outpatient iodine therapy.

Patient Name: \_\_\_\_\_

MRN# \_\_\_\_\_

Referring Physician: \_\_\_\_\_

1. Confirmation that the patient is not pregnant ( $\geq 12$  years). Date of negative pregnancy test: \_\_\_\_\_
2. Is the patient breast feeding? Yes No
3. List the age and relationship of all other household members.  
Who will be the primary caregiver?  
\_\_\_\_\_

4.

Will there be any young children (<10 yrs) or pregnant women at home when the patient returns after treatment? Yes No

5.

How will the patient travel home? \_\_\_\_\_ How long will it take? \_\_\_\_\_  
Who will accompany the patient?  
\_\_\_\_\_

6.

Is the patient scheduled for any other medical tests, procedures, travel or Yes No  
vacation 4 weeks prior or 2 weeks after dosing?

7.

What is the parent's occupation and specific job duties?

8.

Can the patient remain home for the recommended time? Yes/No  
(Not applicable for patients receiving less than 30 mCi of I-131) N/A

9.

Does the patient require any special medical care or living assistance? Yes No

10.

Will patient have use of private bathroom for the next 3 days? Yes No

11.

Is the patient incontinent or have any urinary bladder control problems? Yes No

12.

Will the patient have a private bedroom for the next 7 days? Yes No  
Where is the location of bedroom and adjoining rooms? \_\_\_\_\_

13.

Can the patient maintain at least 10-foot distance from others? Yes No

14.

Is the patient capable of following the radiation safety instructions? Yes No

15.

Are there any other issues that would prevent the patient from being able to  
Comply with the radiation safety instructions? Yes No

Explain:

\_\_\_\_\_  
\_\_\_\_\_

Individual completing Questionnaire:

\_\_\_\_\_  
Date: \_\_\_\_\_

Title:

\_\_\_\_\_

**Table 2.** A sample questionnaire for outpatient treatment with iodine 131.

8. Radioiodine side effects

The side effects of the radioiodine treatment are similar to those of adult patients and include: radiation thyroiditis (usually in patients with a large thyroid remnant) given sufficient <sup>131</sup>I to deliver about 500 Gy (50,000 cGy) [55]; acute and/or chronic parotiditis or submandibular gland sialadenitis (in up to one-third of patients, usually when a large amount of <sup>131</sup>I activity was administered to a patient with a small thyroid remnant) [56]; conjunctivitis and nasolacrimal drainage system obstruction [57, 58], radiation sickness (with a high dose); acute tumor edema or hemorrhage; transient vocal cord or facial nerve palsy [59]; transient amenorrhea or menstrual irregularities [60]; and reduced sperm counts (usually transient) [61]. Infertility is rare but may occur after an accumulated high dose of radiation [62]. The majority of these complications are transient and do not require any specific treatment. However, there are two important side effects that are life threatening, namely, secondary leukemia and pulmonary fibrosis [63]; both relate to the cumulative dose of radioiodine. Unfortunately, there is no definite cutoff regarding the safe dose of <sup>131</sup>I that can be used to avoid these important

complications; the usefulness of the therapy should be assessed prior to each administration, especially where multiple treatments in a single patient are needed, or in patients with pulmonary metastases.

## 9. Follow-up (surveillance)

Recurrence of DTC in children may be seen years after the initial therapy. Thus, long-term follow-up including periodic physical examinations and evaluation involving Tg measurement and neck US are necessary [1]. In recommendation 16 of the ATA 2105 guidelines, postoperative staging is usually performed within 12 weeks after surgery to identify the patients who will benefit from further treatment. In our center, we evaluate the patients 6 weeks after the surgery. Although low-risk patients may be followed up with only TSH-suppressed Tg, for intermediate- and high-risk patients TSH-stimulated Tg evaluation and a diagnostic whole-body iodine scan are typically recommended to determine if there is evidence of persistent and/or recurrent disease [34]. We suggest to evaluate the low-risk patients with Tg measurement and neck US [32]. The measurement of Tg, either “on T4” (basal Tg level) or “off T4” (stimulated Tg level), is the cornerstone of postoperative surveillance programs [2]. Tg is only produced by thyroid cells (normal thyroid cells and differentiated thyroid carcinomas). Consequently, the level of Tg should be undetectable if all thyroid tissues have been destroyed by surgery and radioiodine ablation therapy. However, Tg measurement is not reliable when there is anti-Tg antibody (TgAb) present in the serum. Tg and TgAb levels should be simultaneously measured using the same laboratory and assay technique [47]. Recommendation 23 of the ATA 2015 guidelines stresses that Tg is a sensitive tumor marker in the evaluation, treatment, and long-term follow-up of pediatric DTC, even in children not previously treated with  $^{131}\text{I}$  [47]. The trend in serial Tg and/or TgAb levels is probably more representative of disease status than any single measurement [47]. US is a noninvasive and sensitive method for the evaluation of locoregional lymph node involvement [32]. US is superior in sensitivity to a diagnostic whole-body iodine scan for the detection of involved neck lymph nodes, and it does not require levothyroxine withdrawal. However, the accurate interpretation of US scans in DTC can be complicated by the high frequency of large inflammatory neck lymph nodes in children [4]. According to the ATA guidelines, neck US should be performed at  $\geq 6$  months after the initial surgery, and then at 6- to 12-month intervals for intermediate- and high-risk patients, and at annual intervals for low-risk patients [47]. Follow-up beyond 5 years should be individualized based on the risk of recurrence [47].

A whole-body scan using  $^{123}\text{I}$  or  $^{131}\text{I}$  allows localization of local recurrences or distant metastases, and helps in the decision concerning subsequent radioiodine therapy [5]. Our institutional Protocol for  $^{131}\text{I}$ -whole-body scan is summarized in **Table 3**. Routine evaluation using a diagnostic whole-body iodine scan is not recommended.  $^{123}\text{I}$  is preferred to  $^{131}\text{I}$  for diagnostic imaging. A whole-body iodine scan may be useful in children with known iodine-avid metastases (based on a prior post-therapy scan) at 1–2 years after therapy to evaluate the response to previous  $^{131}\text{I}$  treatment [47]. According to the ATA guidelines, a repeat radioiodine scan is not recommended unless recurrent disease is suspected clinically, based on physical



examination, US, or rising LT4 levels. In our experience, a radioiodine scan was useful when the Tg level was  $>10$  ng/mL (for the evaluation of lung metastasis), when the results of Tg measurement and ultrasound was incongruent, or when anti-TgAb was positive (Tg can be falsely increased or reduced in the presence of a high anti-TgAb level) [34].

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### Indications

Follow-up imaging of patients post-thyroidectomy for thyroid cancer.

Follow-up imaging of patients receiving  $^{131}\text{I}$  therapy for ablation post-thyroidectomy.

### Contraindications

Patient who had a recent (24–48 hours) nuclear medicine scan performed.

The patient must not have had intravenous iodinated contrast agents for at least 1 month. Check with the nuclear medicine (NM) physician.

No recent administration of potassium perchlorate.

### Patient preparation

- If the patient is taking thyroid medication, check with the referring physician if the patient can stop taking it for a minimum of 3 weeks prior to this procedure. Note this information on the requisition.
  - Synthroid should be stopped for 4–6 weeks
  - Cytomel 2 weeks
  - PTU 4 days
  - Tapazole 1 week
  - Methimazole 1 week
- Stop cough syrup, multivitamins for 48 hours before the test.
- Ensure other blood work has been done prior to radiopharmaceutical administration. Patients must have a minimum TSH level of 30–40 mIU/L, and all females who have commenced menstruating must have a documented negative bHCG prior to dosing.
- The patient should be NPO for approximately 2 hours before and 1 hour after receiving the dose by mouth to enhance the absorption of the  $^{131}\text{I}$ .
- The patient should be encouraged to drink plenty of fluids for the next 24 hours to facilitate soft tissue clearance and to flush saliva from the mouth.

### Radiopharmaceutical: $^{131}\text{NaI}$

**Dose:** Based on BSA (body surface area) with a maximum dose of 4 mCi (148 MBq)

### Dose administration

- This product is given **orally** in either capsule or liquid forms.
- Please inform the responsible NM Physician of the patient's arrival prior to dose administration.

- Please make sure to go over the radiation safety guidelines with the patient and parents to ensure compliance. The guidelines should be followed for **2** days if it is a **diagnostic**  $^{131}\text{I}$  TBS (i.e., patient can return to school, etc. the day following whole-body scan). If the patient is getting a **therapeutic**  $^{131}\text{I}$  dose, guidelines will be followed for **7** days. Ensure patient/parents are given the instruction sheet to take with them after dose administration and explain how to page the technologist on call if required.
- Pre- and Postdose counting must be done for all patients having an uptake and scan. Please refer to the  $^{131}\text{I}$  Thyroid Uptake-Probe Method protocol
- For liquid  $^{131}\text{I}$ , administer the dose directly into the patient's mouth. Have a small cup of water handy to use for rinsing the residual dose from the syringe into the patient's mouth—several rinses with the water may be necessary to ensure total dose delivery.
- Patients who are able to swallow a capsule should do so with at least one cup of water.
- Instruct the patient to remain NPO for one more hour and to return for imaging in 48 hours.

#### Acquisition

Images are done 48 hours following diagnostic dose administration.

- Images post- $^{131}\text{I}$  therapy for ablation is performed 7–10 days postadministration.
- Using the high-energy collimator, first acquire an anterior and posterior whole-body pass with the head straight.
- Imaging should be done with a scan speed of 15 min/m using a  $256 \times 1024$  matrix.
- Statics will also need to be done of the RLAT and LLAT skull using a 256 matrix and acquisition time of 10 min/view.
- A 10-minute anterior chest view may also be required but check with the NM physician.
- Patients receiving a diagnostic  $^{131}\text{I}$  dose (4 mCi or less) will need to have an uptake performed at 48 hours as well.
- Have all images and uptake value checked by the NM physician. In most instances, the NM physician will want to speak to the patient before he leaves the department.

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**Table 3.** Institutional protocol for  $^{131}\text{I}$ -whole-body scans. Please note that there are some variations among different institutes for the protocol including the radiation safety precaution.

## 10. Prognosis

Despite the occurrence of extensive disease at clinical presentation, a higher risk of locoregional lymph node involvement, and a higher risk of recurrence, children are much less likely to die from thyroid cancer ( $\leq 2\%$  long-term cause-specific mortality) than are adults [64], and the overall prognosis is better in pediatric DTC [7, 26]. In a study by Minsk et al., the 5- and 10-year survival rates were 99.3 and 98.5%, respectively [65]. Usually, the prognosis is worse in patients aged  $<10$  years [66]. The prevalence of sodium-iodide transporter expression in pediatric DTC metastases is greater than in adults [67, 68]. This is probably one of the reasons for better prognosis and a superior response to radioiodine therapy in children relative to adults, although the risk of lymph node involvement is higher in pediatric DTC [67, 68].

## 11. Conclusion

Although the basis of thyroid cancer management in pediatric population is similar to that of adults, because of longer lifespan and susceptibility of children, the risk of therapy side effects may be higher in comparison to that of adults. Therefore, any treatment in these age groups should be individualized considering the risk and benefit of the therapy in that patient.

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